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In the microwave spectrum, it has long been recognized that refractive effects (tropospheric scatter and ducting) are not only significant but may dominate propagation characteristics. In the propagation of millimeter waves, however, precipitation, atmospheric gases, water vapor, and particulates are generally recognized as the dominant factors; ducting effects have not previously been investigated.

A unique experiment has been designed to assess the effects of the evaporation duct on over-the-horizon signal propagation at a frequency of 94 GHz. Results from five months of measurements made near the Southern California coast strongly suggest that the evaporation duct significantly enhances the received field on a path that is nearly twice the line-of-sight range. Thin evaporation ducts (3 m) are observed to increase the received field to levels more than 50 dB above diffraction. Predictions for thicker ducts (18 m) indicate that the signal can approach levels of free space minus the atmospheric absorption.

An evaporation duct is created above the air-sea interface by the rapid decrease of moisture with increasing height. The strength of the duct is described by the thickness of the trapping layer, which is the height above the surface where the modified refractivity, M, is a local minimum. The thickness, or duct height, varies between 0 and 40 m with a worldwide mean height of about 13 m; however, because evaporation ducts are "leaky," they affect radio and radar terminals above as well as within the duct.

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94 GHZ PROPAGATION IN THE OCEANIC EVAPORATION DUCT

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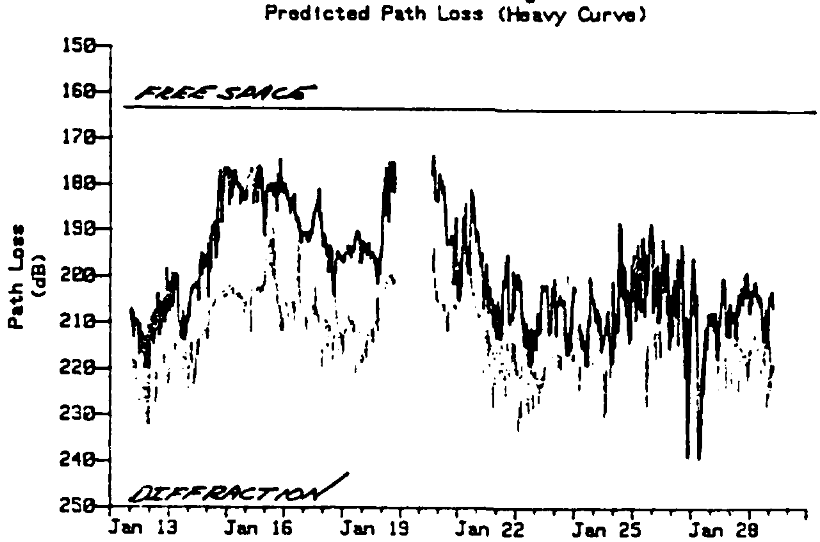
A 40.6 km path, entirely over water, is instrumented to simultaneously record received field strength and surface meteorological conditions. Terminal heights are 5 and 9.7 m above msl, which implies that 18.5 km of the sea surface blocks the line-of-sight path. Transmitter and receiver RF modules are tightly phase-locked to independent crystals and are coupled to 47 dB gain horn lens antennas. An injection-locked IMPATT diode provides an output power of +23 dBm. The signal is tracked with a processing bandwidth of 3 KHz by an HP8568 spectrum analyzer.

The RF system allows measurements of field strength to -118 dBm, which corresponds to a path loss (ratio of received to transmitted power for loss-free isotropic antennas) of 235 dB. In a non-ducting atmosphere, the total path loss between the transmitter and receiver is expected to fall between 245 and 270 dB. Without ducting effects, the expected signals are 10 to 35 dB below the system's sensitivity. Fog and precipitation create additional losses from scattering and are associated with a low evaporation duct height. During heavy fog or rain, the received field falls below the noise floor, and the signal is lost.

A time history of the path loss for the January 1987 measurement period, shown below, compares the observed (light curve) and the predicted (dark curve) path loss. The overestimates of the predicted values early in this period may be a result of (1) the application of a surface roughness model based on Phillips's saturation curve spectrum, or (2) an incorrect assumption that the surface is Gaussian. Later in this period, winds were generally below ~5 m/s, and the agreement between predictions and observation is remarkably close.

Although there is a high confidence in the integrity of the data, the results presented are preliminary. Final results will be available by mid summer of this year.



Millimeter Wave Propagation Experiment
January 13 1987 to January 30 1987